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PROSPECTS FOR HOLOGRAPHY

by

N. Jewtichijew, D. Mirowicki

FOREIGN TECHNOLOGY DIVISION

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Prospects for Holography*

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(prepared by H.K.)

Holography is the method of describing and reproducing wave fields, in order to transmit as fully as possible information about a given object. A complete description of a field of emanation diffused through an object constitutes the most characteristic quality of holographic registration. Thanks to this quality a three-dimensional image is obtained, not distorted by a theoretically unlimited depth of focus.

The distinguishing quality of holographic description is that (the) emanation, diffused through each element of an object, is collected on the objective field in all parts (ranges) of the hologram, so that each of these points contains information about the object. This unique quality ensures a long lasting preservation of information described on the hologram: flaws and cracks and even damaged portions of the hologram hardly diminish the quality of the image reproduced.

Holography can serve for the investigation of any kind of electromagnetic wave fields (radio, optical, roentgen) as well as acoustic (in water, air or in fixed bodies).

There already exists a broad range of problems, which can be successfully solved by holographic methods. The most

important, and most promising possibilities for future application of holography are the following scientific and engineering fields:

- optics
- radionavigation, radiolocation and radioastronomy
- acoustics, hydroacoustics and echo ranging
- technology
- in mathematical machines and cybernetic apparatus
- in physics research
- in photography, film and television

The Application of Holography to Optics

The attractive possibilities in the field of optics are first of all holographic descriptions through heterogeneous and diffusing centers. Several means have been devised for this, one of which suggests the elimination of the effect of heterogeneity of the center by creation of equal conditions for the light beams emanating from the object and those beams coming back. These conditions exist when the returning beam forms on the same object itself. In this manner it is possible to eliminate the influence of a heterogeneous atmosphere in receiving images from cosmic objects. In the United States this method has produced a hologram of a person at a distance of 24 km.

Holographic methods have shown possibilities in the field of amending aberations in optical systems or systems with deformed elements. In particular, there has been devised a method for correcting the aberation of a large

spherical reflector for which a special correcting hologram was utilized.

Also interesting is the use of holograms as optical elements. In this regard it is necessary, first of all, to use holographic zonal screens instead of a lens for focusing the beam of light. Zonal screens of thin plastic are very light and occupy little space. They seem irreplaceable for astronomical research in satellites, because - in contradistinction to a lens - they can be set-up after they have been placed in orbit. The possibilities of focusing the beam with the aid of a zonal screen can also be exploited in laser communications.

Holographic diffraction screens also have indicated a promising future: they are easy to use and have many valuable properties, in particular, with their aid it is possible to regulate the intensity of the spectra of various ranges.

The Application of Holography to Radionavigation, Radiolocation and Radioastronomy

Holography allows the analysis of three-dimensional objects, especially in radiolocation and radioastronomy. It has been determined by experience that holography can successfully be employed for analysis of a different kind of signals initially transformed into an image. These are, for example, a radiolocation signal, speech signals, etc.

The methods of holography can also be applied to the solution of problems in the field of processing non-optical signals. An example that can serve is the processing of signals received from the output of a koherentno - impulse radiolocation station. There also must be mentioned the handling of signals received from elements of great antennas, for example, in devices for radioastronomy.

It appears there is possible use for holography in systems of automatic control (with optical communication). For example - we may already speak of the use of holographic correlation filters for control of flying apparatus by the method of visual orientation (from stars, planets, etc.). Perhaps it might prove of greater interest for cosmic navigation.

The Application of Holography in Acoustics, Hydroacoustics and Echo Ranging

Acoustic holography has developed rapidly in recent years. Its characteristics allow it to make use of very long waves. Acoustic holography can be utilized in defectoscopy, biological and medical researches, echo ranging, geology and archeology.

The technical difficulties in this regard are related, first of all, to the lack of acoustic detectors of large distributing capacity. Holographic echo ranging systems allow, in principle, the combination of all functions of the ideal hydrolocater: discovery of an

object, determination of its position and identification.

The advantages of holographic echo ranging depend upon greater resistance to disturbance as well as the possibility of observation through murky or turbulent centers. Probably in the very near future acoustic holography will serve in solving several practical problems in the field of defectoscopy and bio-medical introscopy.

Ultrasound holographic defectoscopy allows the presentation of the results of research in stereoscopic form, which produces a valuable method of non-destructive control.

The field of medical application for acoustic holography is very broad; the most significant here is its use in diagnosis of various diseases of soft tissues and of cancerous growth within them. It results from the fact that ultrasounds are much more sensitive to changes in chemical composition, density and temperature of the tissues than roentgen radiation. By the holographic method an image of the anatomical structure can be gained as well as of the skeleton and soft tissue. Information has also appeared about the performance of holographic experiments to detect defects in the interior of the eye. Therefore, the problems of the visualization of the acoustic fields, as well as the optical processing of images and sound signals are also very topical.

The Utilization of Holography in Technology

Besides the non-destructive inspection control already (defectoscopy) control of geometric parameters as well as angular or linear displacement, the use of holography in technology is connected with the solution of current

problems of working with materials with the aid of a light beam. In this case the hologram is used as an optical element, focusing laser emanation in the form of a real image on the surface or the interior of a material being worked with; in this way there is allowed a parallel examination at many points.

Holographic methods of examination with the aid of a light beam are especially important in the technology of integrated structures. There are reports that, with the aid of a hologram, a distribution of approximately 1 μm on the surface of a circle of a diameter of 50 mm. is obtainable. There has begun the use of holographic control for photographic patterns, the duplication of matrices and defektoscopy of manufactured goods by the correlated optical filtration method.

The Application of Holography to Mathematical Machines and Cybernetic Systems

There are great possibilities in the field of optical processing of information as well as cybernetics. The first important undertaking is the creation of holographic memory systems for electronic computors. They will allow a significant increase in the capacity of the memory and the speed with which information within that memory is utilized. The advantage of a holographic memory system is the great compactness of material recordable, reaching $10^8 - 10^9$ strikes /cm^2.

The detection and differentiation of known forms in

the presence of a disturbing background is accomplished by using correlating optical filters. They are the salient qualities which allow errorless activity in difficult circumstances, e.g. in displacement, or in the changed geometry of an identified shape. It finds its use in such fields as automatic reading of printed texts, photographic intelligence from the air, etc. In prospect is the building of a diagnostic machine with a three-dimensional holographic memory with the utilization of the associative properties of the hologram.

The Application of Holography to Physics Research

Technical progress in various fields of scientific research is closely connected with the development of holographic methods. This refers to the investigation of the dynamics of elementary particles, microscopic objects, aerosols, and combustion processes in the chambers of jet engines, and finally - aerodynamic and electrochemical research. Broad possibilities for research in other types of processes are opened by holographic interferometry. Its features present the possibility to register the line of a wave diffused through an object, and afterwards reproduce it at another time when the object is no longer present. This makes possible the comparison of wave fronts of the same subject at different times. Such a comparison is done by the interference method.

In holographic interference both waves are deformed to the same degree as a result of defects in optical elements, consequently these deformations do not have an effect on the interferential image.

In contradistinction to ordinary interferometry, holographic interferometry allows investigation of transparent and light reflecting objects, their form, hence, is optional. Interference of light waves of various lengths can be realized, the dynamics of periodic processes may also be observed.

Holographic methods for vibration research have found use in the field of acoustic transformers, or in establishing positions for vibration research, etc. Methods have been devised to detect hidden defects at the base of the formation of nodes and bulges in acoustic waves on the surface of a studied object. Recently new methods were devised for holographic investigation of vibration, models of explosions of thermol currents in fluids and gases, etc. Holographic interferometria is usable not only in physics research, but also in practical industrial application.

There is prospective use for holographic methods in the field of plasma diagnostics. It can indicate the electron concentration and heavy particles in plasma enclosed by walls of irregular formation.

Holographic methods are well suited to record rapidly developing processes. In this regard it is beyond compare. For, using the impulse laser, it can register instantaneously processes and then formulate conclusions, e.g. in the investigation of a stream of gasses issuing from the exhaust of a combustion engine, or in the example of the trail left in the air by a bullet. This method is useful in the development of magnetohydrodynamic generators, the physics of combustion processes, etc.

Holographic methods also have application in nuclear physics for example in recording the trails of charged particles in vesicular cameras, and perhaps for obtaining holograms of long spark discharges which emit trails of charged particles in spark chambers.

The Application of Holography to Photography, Film and Television

These are the most traditional and "obvious" fields for employment of holography. Observing an image reproduced from a hologram, excellent effects are produced not only due to the image being three-dimensional, but additional effects are owed to the halations, which are markedly more dazzling than in regular photography and which "play" by oscillating similarly to that on a holographed subject.

Portraits have been produced with the aid of holography, for example in the USSR a hologram of a person was produced using a unimodular beam of a ruby laser at an energy of 3J in impulse. The best method to accomplish this end is to make a hologram in the volumetric center (on a thickly layered photosensitive plate). Such holograms can be done by using normal sources of light, lasers aren't essential, also it is relatively easy to gain a color image.

Currently there are being devised holographic methods and equipment for the demonstration of large three-dimensional images. Especially interesting is obtaining large

"circular" holograms, i.e. from one point of a 360° image - this might find application, for example, in construction of artistic panoramas.

Much attention has been given to the possibilities for the use of holography in film and television. The attraction of such possibilities is obvious, yet many complex problems are yet to be solved, before holographic cinema or television can be accomplished on a large scale. Holographic methods for recording and reproducing moving, three-dimensional and color images differs essentially from the well-known film production methods.

A closer practical reality is the holographic film as an instrument of scientific research. Holograms have great informational capacity and thus are well suited for documenting moving objects. The basic problem remaining to realizing holographic films is the necessity of producing large holograms, in order to be able to reproduce an image of significant dimensions.

Holography suggests a use as stereoscopic guidance for example in a system for blind aircraft landing. In such a system the possibility arises of recording in a number of holograms the image of an airport with runways. Each hologram gives that runway image which the pilot sees during landing.

The use of holographic method in television opens broad possibilities for the creation of stereoscopic and color television systems. The main obstacle in the transmission of holograms is their tremendous informational capacity, which makes necessary a band 10^4 times broader than

those currently used for television programming. However, some aspects of holographic television have already found use. For example, the R.C.A. Company has produced an adaptor for the television set which allows viewing of a program recorded by holographic methods on polychlor vinyl film. Such equipment will be simpler and cheaper than equipment for magnetic recording and less sensitive to dislocations in the tape and its defects. There are also possibilities for holographic systems for utilitarian television, especially in those circumstances in which three-dimensional orientation is essential.

* This is the nearly complete text of a lecture presented by Prof. D. J. Mirowicki (in his own and Prof. N. N. Jewtichijew's name) on the occasion of an exhibition of Soviet laser technology in Warsaw (April 16-30, 1972).

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